

THE OSTEOGENIC FACTORS IN THE DEVELOPMENT AND REPAIR OF BONE.

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MUCH obscurity exists as to the distinctive role played by the various parts of bone in the development and repair of osseous tissue. Ever since Duhamel, the French naturalist, conceived in 1739, the idea that bone grew from the periosteum, it has been believed that that fibrous membrane produces bone, in the same manner, to use his own words, "as an exogenous stem, grows from the inner layer of the bark." Though histological advance has toned this idea, and though it is now differently formulated, yet a belief of somewhat similar import is still deeply rooted. Apart from its intrinsic merit, as viewed from a developmental standpoint, the determination of the true osteogenic agents, in repair and reproduction of bone is of the utmost practical importance.

It is here proposed to examine the relations which the periosteum bears to the bone, and the osteogenic part performed by the various structures in development and in repair.

The periosteum has been long regarded as the chief factor in the reproduction of bone: more recently the medulla has been stated to be capable of bone regeneration, while a very insignificant part has been assigned to the elements contained in the osseous framework. Observation and experimental inquiry prove that the periosteum is not the potent osteogenic factor which many believe it to be, on the other hand, they show, that the soft tissues enclosed in the osseous tissue, play the chief role in the development and reproduction of bone.

The periosteum is the medium through which the bone

receives a portion of its blood supply. While freely admitting the importance of maintaining the intimate relations of the bone with this vascular membrane, it is submitted that too much fear is expressed that death of bone must follow the partial or temporary elevation of the periosteum. When only a part of a bone is denuded of its periosteum, it is still supplied with blood from the interior; the nutrient arteries and the vessels from the surrounding periosteum, inosculating freely in the medulla and sending a sufficient blood supply to the surface, for the preservation of the life of the bone.

Proposition A.—When the periosteum has been mechanically detached from an extensive area of an adult healthy bone and replaced after the lapse of some hours, union between the bone and the periosteum can take place without sloughing or observable augmentation ensuing.

Obs. I.—An adult healthy man met with an accident, whereby a flap of the scalp including the periosteum, extending from above the right eyebrow to the upper part of the occiput, was raised from the skull, and laid over the right ear. An area of the bone, seven inches long, and from three to four inches broad, was thus denuded of its periosteum. The patient entered the hospital, two hours after the accident, the scalp and periosteum lying until then over the right ear, the periosteum being uppermost. The parts were cleansed, rendered aseptic, replaced, and firm union took place in less than a fortnight, without pus production; three months after the healing of the wound, the part was examined. There had been no shedding of bone, there was no observable osseous thickening, and a linear scar was the only remnant of the injury. Union between the bone and its periosteum was firm and complete, and the patient was in perfect health.

Obs. II.—A lad of 18 years was the recipient of a machinery accident, whereby the soft tissues including the periosteum from the upper two-thirds of the anterior portion of the tibia were peeled from the bone, and lay in a flap which was folded over the lower part of the leg. The bone as minutely scrutinized, was quite bare, and lay exposed for over four hours. The parts were rendered aseptic, accurately brought together, and union was found to be complete when the dressings were for the first time removed at the expiry of three weeks. Seven months after, he was examined, when the part was not only seen to be healed, but as far as could be determined, there was no increase in the thickness of the bone at the seat of injury.

Numerous parallel cases can be cited as occurring both on the bones of the extremities and on those of the skull. These show that wounds which have separated the periosteum from the bone, heal after being brought together, just in the same manner as wounds do, which have separated one soft part from another. Sloughs may form in either case from injury or from arrest of the blood supply.

Proposition B.—The periosteum may be separated from the bone for a period of days by inflammatory products, after the withdrawal of which, reunion between the periosteum and the bone may take place without necrosis ensuing; showing that the temporary separation of the periosteum from the bone, even as a pathological result, is not necessarily attended by death of bone.

Several cases demonstrating this fact have been observed. The following are the most striking:—

Obs. III.—A girl 15 years of age was admitted to the hospital, suffering from a subperiosteal abscess of the right femur of six days' duration. Commencing at the epiphyseal line, at the distal extremity of the femur, it involved at least the lower two-thirds of the shaft, the periosteum being completely elevated from the osseous cylinder, the finger passing freely round the bone, and the latter being bathed in pus, ten ounces of which were evacuated by a series of incisions, through which perfect drainage was maintained. At the end of three weeks the wounds made for the drainage of the part were cicatrized, with one exception, which became healed at the termination of the fifth week. The limb was completely restored. Six months after, on comparing the one limb with the other, there was no discernible thickening. The wounds had not reopened in the interval, and the patient possessed the full function of the limb.

Obs. IV.—Another instance occurred in a girl æt. 18 years, the subperiosteal abscess involving the femur from the great trochanter to the condylar epiphyseal line. The symptoms of the attack had been present for eight days, though at what precise period the inflammatory action had passed into suppuration was not ascertained. The whole of the anterior part of the shaft was denuded of periosteum, behind, near the situation of the femoral nutrient vessel, there were some adhesions of the periosteum to the bone. The constitutional symptoms were marked. Free linear incisions were made into the

limb at various places, so as to prevent the possibility of pus accumulating under the periosteum. Complete recovery was effected. Two months subsequently, there was a thickening of the femur peripherally, especially at its lower extremity. There was no necrosis. The limb was restored to complete use. One year afterwards, the patient was examined. The peripheral increase had not augmented. It was found on measurement to be the same as it was when she left the hospital ten months previously. She walked to and from her work daily, a couple of miles, and only experienced fatigue and a sense of weight in the limb, when she over-exerted herself.

Obs. 5.—A delicate girl, *æt.* 12 years, was seen with acute periostitis of the tibia of four days standing. The constitutional symptoms were not so marked as in the other case, but the pain was excruciating. There was slight swelling of the tissues in front of the tibia. A couple of free longitudinal incisions were at once made down to the bone, giving vent to several ounces of slightly turbid serum. The periosteum was found to have been stripped from the bone, the bent probe passing freely round its circumference over the lower two-thirds of the shaft. The constitutional symptoms disappeared within twenty-four hours. The first dressing was removed at the end of a fortnight, when the wound was found healed. One year after she was examined, and at several subsequent periods. The limb was in no way increased in diameter; she had perfect use of it, and she stated that she had no pain or ache since she left the hospital.

No one will understand that cases of this kind always end so well. These are merely described as what occurred on those occasions, and illustrating the points at present at issue.

In observations three and four, the fact that the periosteum was stripped from the bone, over the areas indicated, was demonstrated, by the probe, the finger, and in part by the eye itself. In these cases the nutrition of the bone must have been maintained through the medulla by means of the nutrient vessels. It proves that the separation of the periosteum from the bone for some days does not necessarily result in necrosis. In observations three and four, there was probably a considerable dilatation of the Haversian canals, interstitial absorption taking place as a preliminary result with a subsequent redeposition of new bone.

Proposition C.—The periosteum covering a portion of bone may be completely destroyed or permanently removed, yet the denuded bone may not only retain its vitality, but may throw out cells which will cover it and form a new periosteum.

Instances of this kind are very numerous.

Obs. VI.—A young adult man received an injury to his left lower limb, whereby the whole of the soft tissues were removed from a portion of the inner and anterior aspects of the tibia, and the bone was scraped and furrowed. The osseous area thus laid bare was three inches in length by about two in breadth. The elevated flap of the soft parts, including the periosteum, was so crushed that it died, leaving the bare bone exposed. Three days after the injury the surface of the bone presented a highly vascular appearance, and by aid of a hand glass numerous small points of granulations were discerned scattered over its surface. On the fifth day these islands of granulation tissue were greatly enlarged, on the seventh many of them had coalesced, and by the tenth day they had united in great part with the granulation tissue at the periphery of the wound. On the fifteenth day the bone was completely covered by a uniform layer of granulation tissue which at the end of six weeks had become completely covered by epidermis.

In this instance the vitality of the bone was evident from the outset, and the granulations sprouted from the osseous surface by way of the Haversian canals, and filled up the furrows which had been dug in the bone by the injury. It was remarked that the deepest trenches were those which were soonest filled with granulation tissue, and several small areas where the cortical layer had remained intact, were last to become covered with granulations. That is to say, the parts which had previously been in immediate contact with the periosteum showed a vitality much less active than the deeper portions of bone. Structural differences account for this, the most superficial part of the cortical layer of an adult healthy bone, being more dense and less vascular than the deeper portions.

The same phenomena are not unfrequently seen in compound fractures, where the extremities of the bones have been subjected to direct violence, but probably it could not be better exemplified than in the following instances:

OBS. VII.—A man, *æt.* 35 years, had his arm at its upper third crushed between two revolving pinion wheels. Four longitudinal gashes, each exposing the bone, were inflicted on the soft parts equidistant from each other, each measuring four inches in length by one inch in breadth. The tissues of the whole circumference of the arm at its upper third were much bruised, the muscles reduced to pulp, the vessels and nerves lying exposed and separated from one another, while the upper third of the humerus had sustained a comminuted fracture. The proximal extremity of the lower portion of the shaft lay exposed, being visible through each of the four wounds. Not only was it denuded of its periosteum, but for two and a half inches the whole circumference of the osseous cylinder had been subjected to a force which had crushed off the entire cortical dense portion, leaving a porous osseous frame work, enclosing cancellated tissue. It was evident from the state of the bruised and lacerated strips of soft parts which partially surrounded the bone, that little sustenance could be derived from them for the support of this portion of the bone. Therefore, if this portion of bone were to live, it would require to depend upon its own vitality, obtaining its blood supply from the lower part of the shaft. Much sloughing of the whole of the soft parts ensued, round the entire circumference of the upper third of the limb, with the exception of a thin strip, about half an inch in breadth, surrounding and including the brachial vessels and nerves; so that with this exception the continuity of the entire thickness of the soft parts from the skin to the bone was severed over an area of three to four inches in longitudinal diameter. A single stroke with a pair of dressing scissors would have sufficed to complete the severance of the limb. The proximal two and a half inches of the humeral shaft deprived of its cortical layer and destitute not only of its periosteum, but all of its soft covering lay free on all sides.

It was with difficulty that this portion could be fixed to the upper fragment, which likewise at its extremity was denuded of soft tissues including the periosteum; as wire sutures cut through the softened cancellated tissue whenever strain was placed upon them. The bones had therefore to be held in position by means of chromicized catgut, applied in a series of circles surrounding the fractured extremities, as is done in splicing. This catgut intervened between the strip of tissue containing the vessels and nerves and the bone; but the individual whorls of the catgut were placed at such intervals as to allow of the bone being observed.

The parts were subjected to a daily scrutiny, and as the bone lay thus exposed the various changes were easily ascertained.

This exposed portion of bone never lost its vitality, retaining from the outset its life-like hue. By the fifth day it showed increased vascularity; by the tenth numerous granulation buds were seen sprouting from the interior of the bone, and they increased so rapidly that they soon covered its entire surface and mounted round the strands of catgut. Subsequently, the granulations which had formed round the vicinity of the main vessels, became united with those proceeding from the bone, and at a somewhat later period the latter united with the granulations from the proximal and distal aspects of the hiatus in the soft parts, which had been left by the sloughs. Once this was accomplished, cicatrization went rapidly on, though twelve weeks elapsed before it was complete. The fracture united firmly. There was no osseous necrosis, but there was a perceptible augmentation in the circumference of the shaft at the seat of the injury. The cicatrix firmly adhered to the bone, and though the shaft is continuous, there is still a gap of several inches existing between the muscular bundles which have become attached to the shaft; the upper portion of them above, and the lower parts below the seat of fracture.

A very interesting point in connection with this case, is the power which the patient now possesses over this arm. It was believed that the forearm alone would be of service to him, but he can raise his arm above the shoulder, though he has more power below that level; and he states that a year subsequent to his dismissal from the hospital he was engaged as a stoker, throwing into a furnace 40 tons of coal per week. The particular mechanism in this deranged muscular apparatus relatively to its osseous lever will afterwards be referred to.

This case therefore illustrates the fact that two and a half inches of the shaft of a long bone, bereft of its outer dense cortical layer, along with its periosteum, and freed for some days from all contact with living soft tissues, except a narrow strip surrounding the main vessels and nerves, cannot only retain its vitality, but throw out sufficient ossific material to enable the fractured extremities to unite firmly together and to add to its circumferential thickness, to restore its density, and to clothe itself with a new fibrous tissue layer or periosteum. The whole of its nutrition must have been supplied for a considerable period entirely from the interior of the shaft.

OBS. VIII.—A boy, æt. 3½ years, had the periosteum stripped from the whole tibial diaphysis of one limb, with the exception of a small

portion posteriorly, which surrounded the nutrient vessel. This was the result of acute suppurative periostitis, the symptoms of which had lasted for nearly seven days, previous to his admission under observation. The local appearances and the constitutional symptoms were marked. Several linear incisions were made exposing the whole length of the tibial diaphysis. The shaft was quite bare, the periosteum having been separated from it by an accumulation of pus. This had formed round its whole circumference extending from the one epiphysis to the other, with the exception of a patch posteriorly, surrounding the nutrient vessel. Owing to the distention of the periosteal sheath by pus it had become stretched so as to permit the finger to pass round the entire circumference of the shaft. When the parts had been thoroughly washed with a carbolyzed solution, the bone appeared like a piece of white porcelain.

Between the periosteum and the bone there was placed a series of layers of sublimated gauze. This was so arranged as to separate the periosteum from the bone round its whole circumference, and over the entire length of the shaft, with the exception of part posteriorly, which surrounded the nutrient vessels.

Forty-eight hours afterwards the stuffing was removed, and the parts washed and inspected. The bone thus separated from its periosteum had all along its shaft the aspect of life, with the exception of a small portion which was doubtful. The stuffing was re-applied as before. On the fifth day the stuffing was removed from between the periosteum and the bone, when the shaft presented a pinkish blush, with the exception of a portion toward the upper extremity of the tibia which measured three-quarters of an inch in length by half an inch in breadth. This small part remained white and evidently dead. In many places on the shaft granulations were beginning to appear. The stuffing was again re-applied.

On the sixteenth day, after the operation, the whole shaft of the tibia was seen to be covered by granulation tissue with the exception of the small portion previously spoken of, which lay as a white island in the midst of a red sea. The periosteum was also covered by a layer of granulation tissue which was quite soft and pliable. There was no hardness indicative of bone formation detectible in this layer. The stuffing was renewed.

At the end of the fourth week it was found that the granulation tissue covered the entire shaft hiding it completely from view, and the small portion of bone which had been previously noted as bare was now easily detached. It was a scale about an eighth of an inch in thickness, its extremities and under surface showing traces of erosion

while the external surface was smooth and white. The granulation tissue covering the bone had a firm cartilaginous feeling, and though of some thickness could be moved latterly with difficulty, and felt firmly fixed to the shaft. It was only the most superficial portion of it which was soft and pulpy. In marked contrast to this was the granulation tissue covering the under surface of the periosteum which could be easily compressed by the finger and thumb. The two layers of granulation tissue were now for the first time permitted to come together and they soon coalesced. The wounds rapidly cicatrized, and there was a slight peripheral augmentation.

His constitutional state improved from the fourth day, when his temperature had fallen to normal, and the albumen disappeared from his urine.

This case shows first that there is a sufficient amount of blood furnished to the bone, to sustain it for weeks, independent of its periosteal supply.

In this case it received its supply through the nutrient vessels at the upper portion of the tibial shaft. Had these nutrient vessels also been occluded necrosis of the entire shaft would probably have ensued.

Second, it shows that though the periosteum be separated from the entire circumference of the greater portion of the shaft of a long bone, death of that bone does not necessarily ensue. The fact that in this case a small scale like portion of the external table of the shaft did die, and was so rapidly shed by the living osseous tissue, was proof of the activity of the vital action of the bone itself. Thirdly, that the periosteum which was kept separate from the bone did throw out granulation tissue, but it was soft and supple and showed no evidence of bone growth at the termination of the thirty-first day. Fourthly, whereas, at the same time the mass of granulation tissue thrown out from the bone itself felt firm and almost cartilaginous, and that the ultimate osseous thickening round the tibia corresponded to the amount thrown out by the bone itself. Fifthly, this case raises the question whether all, or at least many of these cases of acute periostitis, do not in reality heal from the bone tissue itself, even where there is ensuing thickness of the osseous periphery. This has generally been

attributed to the periosteal growth. This again would depend upon the preservation of the nutrient vessels.

Proposition D.—*A portion of bone which has its continuity severed on all sides, and at the same time has had all its periosteum removed is capable, of living and growing.*

Observations in support of this statement are very numerous. The following may suffice to establish the fact:

OBS. IX.—A man in good health, æt. 40 years, received a compound comminuted fracture of the right tibia about its middle third. A portion of the inner and posterior aspect of the tibia was completely detached, and lay obliquely between the upper and lower fragments. It measured an inch and a half long, an inch broad in the centre, and three-quarters of an inch in thickness. It was entirely destitute of periosteum. It was removed, washed in carbolized solution and replaced in its proper position. For ten days the whole of its inner surface lay exposed in the wound, its surface presenting a whitish appearance with minute red spots. At the termination of this period a pinkish blush suffused the whole surface of the fragment. In looking at this through a hand glass it was seen to be composed of minute blood vessels ramifying through the cortical layer, and presenting themselves in leashes at the orifices of the Haversian canals. Soon granulation tissue was apparent to the naked eye forming innumerable islands over the surface and finally coalescing. There was no necrosis. The wound soon cicatrized and healed firmly. At the end of eight weeks perfect osseous union had taken place.

OBS. X.—A healthy man, æt. 36 years, suffered from a depressed comminuted fracture of the frontal bone of the skull, received from the kick of a horse. The depressed area was about two inches in diameter. The frontal sinuses were opened, and both internal and external tables of the skull were found to be crushed on to the dura mater, and the longitudinal sinus was penetrated.

A portion of the external table about two inches long and half an inch broad, was removed; then six fragments of the internal table, each measuring, roughly speaking, one-quarter by one-eighth of an inch, were taken away, and lastly, a portion measuring one inch by three quarters, forming part of the vitreous table of the frontal fossa of the base, which had been loose and dislocated was likewise removed. All of these portions were destitute of periosteum. They were taken out,

cleansed, closely inspected, placed in an antiseptic solution and kept there until required. Fifteen minutes elapsed during which the wound was otherwise attended to, the bones were afterwards reimplanted, slight apertures being left for drainage. The wound healed under one dressing, and five weeks afterwards the reimplanted bones were found to be quite firm, a solid barrier having been formed instead of the large pulsating gap, (P. G. Ward 29, 1884) which otherwise would have been left.

Obs. XI.—A weak, ill fed boy, *æt.* 9 years, was admitted into ward 29 in January, 1884, suffering from a compound comminuted fracture of the skull with penetration of the brain substance, received about two hours previously by the fall of debris from a chimney. The brain symptoms are not referred to here.

There was a wound situated over the left side of the head of a somewhat crescentic shape and extending from above the middle of the left eyebrow, to an inch behind the auriculo-bregmatic line. The scalp was torn into several pieces, some of which lay over the ear. All of them were much bruised and lacerated. The skull was found shattered from an inch above the middle of the left eyebrow to a point half an inch behind the auriculo-bregmatic line. The depressed portion was somewhat elliptical, with very irregular margins. It measured at its broadest part two and a half inches. All of these portions of bone were depressed below the level of the skull, most of them having penetrated the brain membranes into the brain tissue. Those portions of bone were all elevated. It was found that they consisted of eleven pieces, the periosteum having been scraped from all of these with the exception of the most posterior one, which was only partially denuded. Many of them were infiltrated with lime debris, brick dust, etc.

These pieces, as they were elevated, were placed in an aseptic atmosphere. They were then pared with a chisel in order to remove the debris. This was especially necessary over the external surface where they had been scraped and ingrained with dirt. They were afterwards thoroughly washed in an aseptic solution, divided into fragments and replaced. In this way a mosaic work of fourteen pieces of bone was formed. It was difficult to retain these in position owing to four things. First, to the extent of the osseous defect; second, to the fact that the dura mater had been so extensively lacerated and torn that it formed a very irregular floor to rest the fragments upon; third, to the great bruising and crushing of the scalp, which rendered it difficult to bring the several pieces into apposition, and made sloughing of a part of it almost certain; and fourthly, to the

force of the cerebral impulses which caused a distinct movement of the fragments, producing crepitation by the one rubbing against the other. It was feared that owing to these four circumstances some of the fragments would be shed. It is to be borne in mind, that the periosteum had been by the injury entirely removed from all these fragments except the most posterior one; and that most of them had to have their external surface pared with a chisel. The soft tissues were brought together as well as possible and the wound was dressed.

On the sixth day after the operation the wound was examined. A portion of the anterior aspect of the flap which was lacerated and contused had sloughed, and already the process of separation from the living part had commenced. On the tenth day the wound was re-examined, and this portion of the slough was removed. It was then seen that four fragments of bone were exposed, two of which lay side by side, and presented a striking contrast. The one was suffused with the pinkish blush of life, the other with the pallor of death. The conditions of the remaining exposed fragments was doubtful, one of them, however, being very pale. On the twenty-first day at the next dressing, two pieces of bone were found to have shed, while all the remainder had lived, the wound was all but healed. At the termination of a month it was firm.

Obs. XII.—A fairly healthy man (J. B.), æt. 26 years, was admitted to ward 29 in 1885, suffering from a compound comminuted fracture of the lower third of the left tibia and fibula received by a blow from a screw propeller of a steam ship. There were two large wounds freely communicating with one another. The one was situated anteriorly, and the other posteriorly, and each measured about two and a half inches by one inch in diameter. The bones were so shattered that one could see through the leg from one wound to the other. The bones were divided into numerous fragments, measuring about quarter of an inch to an inch in length, and of very variable diameter, all completely detached from one another and many of them destitute of periosteum. Besides there were two portions of the tibia, each about two inches in length, by about an inch in breadth, which lay detached and buried in the muscles. Several of these pieces had to be lifted out, one of them measured an inch and a quarter in length by an inch in breadth. It had no periosteal covering and consisted chiefly of the dense tissue of the bone. There were thus about three inches of the length of the shaft of the tibia, which had its circumference broken into fragments, which were strewn among the lacerated and chopped up muscles and periosteum. There were many long shreds of periosteum which lay twisted and acutely bent over the proximal fragment.

and also a few over the distal portion of the shaft. These had to be elevated and detached, as they were infiltrated with dirt. All these portions of bone were picked from amongst the bruised muscles, they were then carefully cleansed, washed in antiseptic solution, and re-adjusted into the form of the shaft, the muscles having been drawn together posteriorly, in order to form a floor upon which the various osseous fragments might rest, many of the pieces having to be held together by strands of catgut. Six weeks subsequently, when the limb was examined for the first time, the larger wounds were found to be practically healed, some granulation tissue covering a small portion. Ten weeks subsequently, when the wound was looked at for the second time, the wounds were seen to be firmly healed, the bone was not quite firm. At the end of fourteen weeks it was found to be completely consolidated.

Eighteen months afterwards, patient revisited the wards to report himself. He was then able to walk twelve miles without fatigue. There never had been any break in the skin since his dismissal, and there was only a little thickening at the seat of injury.

Proposition E.—Not only do detached portions of bone deprived of their periosteum live when reimplanted in their original position, but such portions are capable of living after transplantation. Parts of deeper layers of bone which had no periosteal connection have been transplanted and have lived and grown.

OBS. XIII.—The subject of this observation was a patient in ward 22, Royal Infirmary, in 1878, and the facts concerning him have been published in a communication made to the Royal Society, London, in 1881, and to the Academy of Science, Paris, in the same year. The reader is referred to the proceedings of the former body for further details, as a résumé of the points bearing on the present subject are alone alluded to here.

This boy, æt. 2 years, lost the shaft of his right humerus from suppurative periostitis, ending in complete necrosis of the humeral diaphysis. The necrosed bone was removed about nine weeks after the onset of the periostitis, leaving the layer of granulation covering the periosteum intact and forming a tube which was kept patent by dressings suitably inserted until the whole space had granulated up. No bone grew from the periosteum, except a small part next the proximal epiphysis, where at the outset the periosteum was found covered by plaques of adherent osseous tissue. From the whole extent of the

remainder there was no osseous deposition, the result being a flail like arm. Fifteen months subsequently he returned to the infirmary, his parents desiring that the arm should be removed, it being worse than useless, inasmuch as he required the other hand and arm to look after the flail-like one which was constantly dangling in the road. The condition of the arm was as follows: The bone had not increased in length since he left the hospital. When the limb was allowed to hang by the side, the measurement from the tip of the acromion process to the distal extremity of the humeral shaft was nearly two inches. In form, the proximal fragment was conical tapering from the rounded head to a narrow spike-like extremity. From this to the condyles there was a complete absence of bone, there being nothing but soft tissues in the gap. The muscular power was good, but when he attempted to raise his arm a contraction of the muscles took place, the condyles being drawn toward the proximal extremity, while some fibres of the deltoid raised the spike like process of the upper portion, causing it to project, as if about to penetrate the skin. Here the action ceased, the soft parts in the gap appearing like a rope during the muscular contraction. He could not raise his forearm to his breast. If one caught his arm firmly with the hand placed over the gap, so as to keep the condyles fixed, and separate from the upper fragments, then the patient could elevate his forearm toward the chin. The power was there, the lever and fulcrum were wanting. It was determined to supply these by transplantation from other human bones. In the wards there were numerous cases of marked anterior tibial curves, from which wedges of bone had to be removed, and these were utilised as transplants. An incision was made into the upper third of the humerus exposing the head of the bone. Its extremity for fully a quarter of an inch was found to be cartilaginous. The cartilaginous spike-like process was removed, leaving there a portion of bone which measured one inch and three-quarters from the tip of the acromion process. From this point a sulcus about two inches inches in length was made in a downward direction between the muscles. The former presence of bone was no where indicated, and there was no vestige of periosteum, and the sole guide as to the correct position into which the transplant was placed was an anatomical one. Two wedges of bone were then removed from the tibia of a patient *æt.* 6 years, affected with anterior curves. The base of these osseous wedges consisted of the anterior portion of the tibia, along with its periosteum, the wedges gradually tapering toward the posterior portion of the tibiae. After removal they were cut into minute fragments with the chisel, quite irrespective of the periosteum. The bulk of the frag-

ments had no periosteum adhering to them, they having been taken from the interior of the bone. They were then deposited into the muscular sulcus in the boy's arm, and the tissues drawn over them, and carefully adjusted. The wound healed without pus production. Two months after a portion of bone an inch in length and three-quarters of an inch in thickness, was found firmly attached to the upper fragment of the humerus. In removing the finger from the head of the bone toward the graft, the latter could be easily distinguished by the sudden increase in the breadth. Now instead of the former sharp spike, the upper fragment ended in an obtuse terminal.

Two other wedges of bone of larger size than the first were similarly dealt with and inserted, two months subsequently to the first graft, and a third couple were placed in position five months after the first. These filled up the gap in the arm to the extent of four and a quarter inches, the arm then measured six inches in length. Soon the utility of the arm was greatly restored.

Seven years afterwards he was seen and examined. The shaft of the humerus was found to have increased in length by one and three-quarter inches, being now seven and three-quarters, and it had increased in circumference to a marked extent and had assumed a somewhat irregular shape. The length of the sound arm had, however, considerably outstripped the length of the transplanted humerus. The patient could use the arm for a great many purposes, taking his food, adjusting his clothes, and in many games.

What conclusions may be drawn from the data supplied by these experiments? Some have asked whether it was not possible that old periosteum remained in the arm and produced new bone, the operation of transplantation having acted as a stimulant to it. Had periosteum existed between the condyles and the upper part of the humerus, and if periosteum possessed an osteogenic power it had ample time to reveal itself by osseous growth during the fifteen months which had elapsed between the removal of the dead bone and the transplantation of the new. Again, in opening the sulcus between the muscles for the reception of the transplants, neither periosteum nor any like fibrous membrane was seen, so much so, that it was only by recognizing the relative positions which the muscles ought to occupy toward the humerus that a guide to the correct position of the transplants was gained. Further the growth of

bone in the arm was at first only commensurate with the insertion of the transplants. There was no indication of the osseous growth in the vicinity of the transplants which might have arisen from the supposed stimulated periosteum. Finally, the solid humerus still retains the irregularities of shape which the transplants were permitted to assume in the tissues. So that there is not an iota of fact to support the supposition that the new bone grew from old periosteum. The whole of the grafted portions, united to one another, and to the extremities of the epiphysis, by means of osseous increments, forming a solid rod, four and a half inches in length. Before these transplanted portions of bone could have united, there must have been a proliferation of the bone forming elements contained in the grafts. Had they united by fibrous tissue union, the arm would still remain mobile; but the union was solid. When the condyles were rotated the head of the humerus moved with it. In further illustration of the vitality of the transplants and the growth of the new bone from them, there is firstly, the evidence derivable from the callus thrown out between the second and third transplants, after their extremities were refreshed, the same phenomena being observed here as in an ordinary case of ununited fracture. The portions removed from the extremities, on refreshing the bones, were seen when submitted to microscopic examination to present all the aspects of growing bone. Secondly, the bone became sensibly thicker at the points where they were drilled for the reception of pegs. All these are evidence of the actual growth of bone from the transplants. Besides, the whole bone has now decidedly grown in length and thickness, the latter being at least due to the growth of the graft. When the extremities of the second and third transplants were refreshed, the appearances of both bones were that of living osseous tissue, surrounded by a thin vascular membrane, which bled when it was scraped up, much in the same way as periosteum would under similar circumstances. This membrane did not resemble the thick, semi-vascular capsule, which is found surrounding dead tissue in process of being absorbed. It was in fact a new periosteum.

Remarks.—In this instance it is probable that at the outset

of the disease, the nutrient artery of the humerus had been occluded or separated in the intensity of the suppurating process. The shaft deprived of all nutriment, not only from the periosteal vessels, but also from the nutrient ones, died *en masse*. The periosteum remained intact. Adherent to its upper margin were a few osseous plaques, which had been detached from the bone, these being in immediate contact with the epiphysis. These plaques grew in the form of a spindle-shaped rod, which formed the spike-like cartilaginous extremity of the proximal fragment. All the rest of the periosteal sheath which remained produced no bone, and showed no sign of its existence fifteen months afterward. It became completely absorbed. The arm had been kept fixed, all movement being prevented, the periosteal sheath was kept separate till it filled up with granulations. It had every opportunity of producing bone, but it did not do so, and instead it became absorbed.

It must be borne in mind that the resection of the necrosed bone was not undertaken at once. About seven weeks were permitted to elapse between the death of the bone and the removal of it. It was left thus long in the hope that the time allowed would have been taken advantage of by the periosteum in throwing out plaques of bone. This, however, it could not do, the death of the shaft having been sudden and absolute, not permitting an escape of osteoblasts into the periosteum.

Cases of subperiosteal resection of the humerus have elsewhere occurred in which the bone has not been reproduced. Nedopil performed a subperiosteal resection of the humerus in a boy 12 years of age, the shaft not being reproduced. Neudorfer also mentions a case in which the humeral shaft was not reproduced after subperiosteal resection. (Professor D. Vogt, *Die Chirurgischen Krankheiten der Oberen Extremitäten*, p. 225, paragraph 212). In all such cases it is probable that the nutrient vessels have been occluded or blocked. If so the whole blood supply, that from the periosteum as well as from the nutrient vessels, would be cut off from the bone, and necrosis would be inevitable, so that a great deal depends upon the safety of the nutrient vessels which in cases of periostitis

is often the determining factor in the question of life or death of the shaft.

Obs. XIV.—An interesting fact was observed when a minute portion of bone was broken off from the deeper layer of new osseous growth, which consequently was far removed from any periosteal connection, and which was found to be capable of growing in the midst of granulations.

After removing a fibular central sequestrum, a hollow cylinder of new osseous tissue was left. On introducing a piece of specially prepared sponge into the interior of the osseous cavity, a spiculum attached to the internal surface of the osseous cylinder was detached and carried further into the interior of the osseous cavity, where it remained entangled in the meshes of the sponge. At the end of eleven weeks, when for certain reasons the sponge was removed, it was found partially filled with granulations and young connective tissue in the midst of which the spicule of bone was seen and attached to and surrounding its conical points there was a rounded knob of cartilage. The spicule measured three-sixteenths in length and the cartilaginous knob was almost one-eighth in its greatest diameter. When this tissue was decalcified it was submitted to microscopical examination. The cartilaginous nodule was intimately connected with and springing from the osseous spicula. It consisted of ossifying cartilage. At the further extremity of the spicula, where there was no cartilage, there was a portion of the bone which showed a few lacunar defects filled with leucocytes. A portion of the bone therefore nearest the periphery, and therefore perhaps subject to friction, occasioned by the arterial pulsations intensified in a confined space, was undergoing absorption, while its opposite and most central extremity was throwing out ossifying cartilage. This growth of bone took place under adverse circumstances at a distance from immediate contact with bone, subject to continual pulsating movements, and in the midst of a sponge filled with granulation tissue, a portion of which had suppurated. There was here no possibility of periosteal connection; there was no bone marrow, as the central sequestrum had just been removed, and the whole cavity was thoroughly washed with a free stream of watery solution of carbolic acid.

[TO BE CONTINUED].